

# The AIRS V5 Ozone Validation



- An Outline of the Paper Submitted To JGR (Presently under review).  
(Let me know if you wish a copy of the paper)

**Evaluation of Atmospheric Infrared Sounder (AIRS) Ozone Profiles and Total Ozone Retrievals with Matched Ozonesonde Measurements, ECMWF Ozone Data, and Ozone Monitoring Instrument (OMI) Retrievals\***

- On-Going Activities and Upcoming Plans

**Murty Divakarla, Christopher Barnet, Mitchell Goldberg, Eric Maddy, Xingpin Liu, Walter Wolf, Lawrence Flynn, Gordon Labow@, Xiaozhen Xiong, Jennifer Wei, and Lihang Zhou**

**NOAA/NESDIS, Camp Springs, MD 20746; @NASA/GSFC**

**Bill Irion and Mike Newchurch  
NASA/JPL, Univ. of Alabama**

**Thanks To:**

**Shuntai Zhou, NOAA/NCEP, Craig Long, NOAA/NCEP, Eric Beach NOAA, Bojan Bojkov NASA/GSFC**



# What We Did

- Validation of AIRS Retrieved Ozone profile, and Total Ozone with WOUDC O<sub>3</sub>SNDS and Total Ozone Measurements.
  - » Both V4 and V5 Versions (Retrieval Emulations at NOAA/NESDIS)
  - » AIRS Ozone Profile Retrievals with O<sub>3</sub>SNDS
  - » AIRS Total Ozone with BD Measurements
    - Simultaneous Aqua-AIRS, Aura-OMI and WOUDC Total Ozone Measurements
    - Individual STNs, NH, SH, Tropics, Global
- Analysis of AIRS Global Ozone Grids
  - » Using Gridded Monthly Averages (2004 and 2005) of AIRS, OMI, SBUV and Global Forecast System (NCEP-GFS) – Seasonal Trends, Patterns
  - » How Point Measurements/Validation Corroborate to Global Perspective Seen with the Global Grids
  - » Annual Cycles

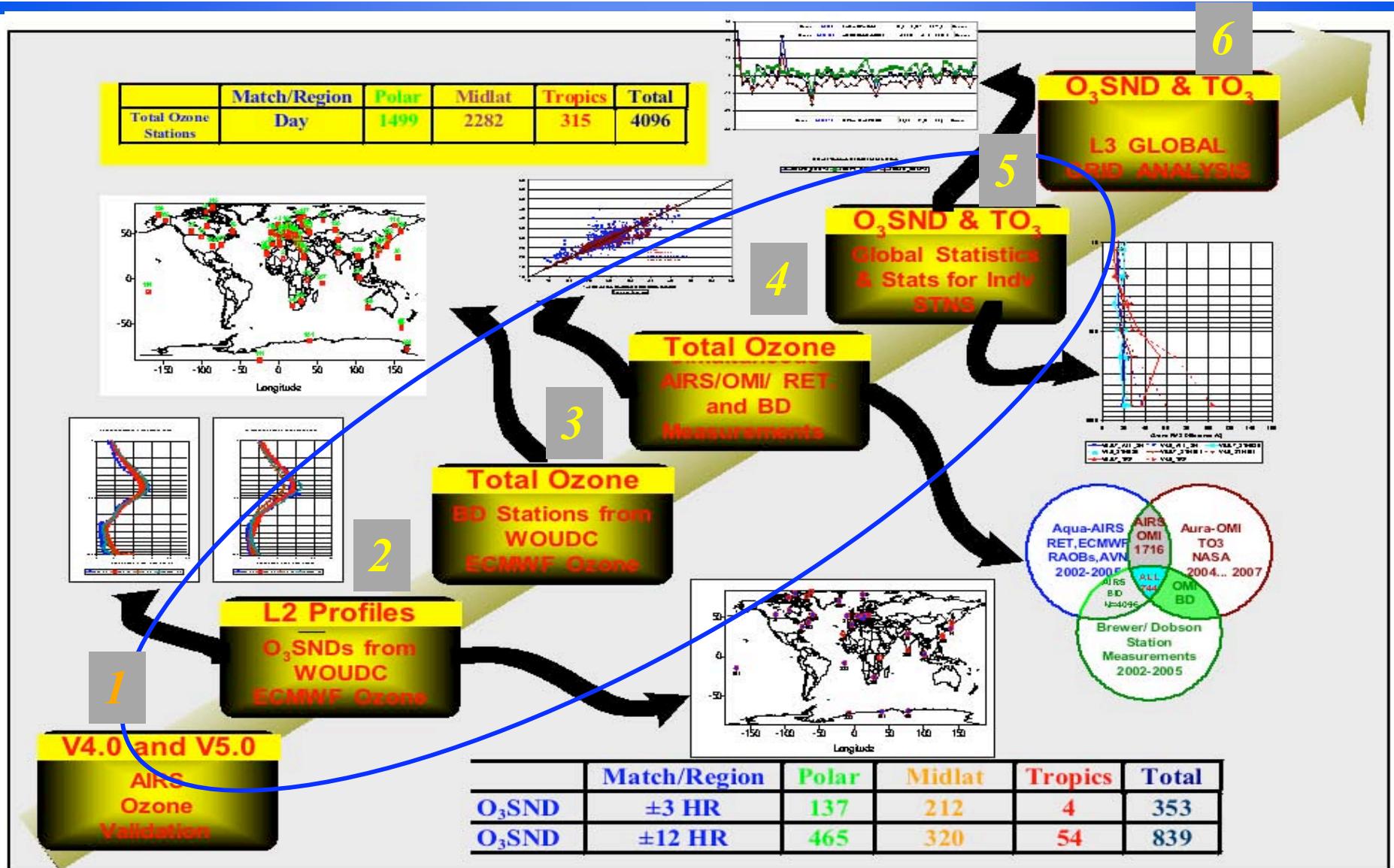


# Data Credits and Acknowledgments

- » Ozone sondes and Brewer Dobson Measurements
  - WOUDC Ozone Data ([www.woudc.org](http://www.woudc.org))
- » Gridded Monthly Averages for AIRS, SBU, OMI and GFS for the Years 2004 and 2005
  - AIRS V4 and V5 Retrievals Emulated at NOAA/NESDIS
    - Global Grid Resolution:  $3^{\circ} \times 3^{\circ}$
    - Generated by NOAA/NESDIS/IOSSPDT – V4 and V5 Emulation
  - SBUV/2 on NOAA-16
    - Global Grid Resolution:  $2.5^{\circ} \times 2.5^{\circ}$
    - Monthly Data Provided by Shuntai Zhou, NCEP
    - Download : <ftp://ftp.cpc.ncep.noaa.gov/SMOBA>
  - Ozone Monitoring Instrument (OMI) on Aura
    - Global Grid Resolution:  $1.25^{\circ} \times 1.0^{\circ}$
    - Downloaded from:
    - [ftp://toms.gsfc.nasa.gov/pub/omi/data/monthly\\_averages/ozone](ftp://toms.gsfc.nasa.gov/pub/omi/data/monthly_averages/ozone)
  - Global Forecast System (GFS)
    - Monthly Data provided by Craig Long
    - [ftp://ftp.cpc.ncep.noaa.gov/long/gfs\\_ozone/month/](ftp://ftp.cpc.ncep.noaa.gov/long/gfs_ozone/month/)



# The AIRS Ozone Validation Ladder





# What We Did and What is Achieved (1)

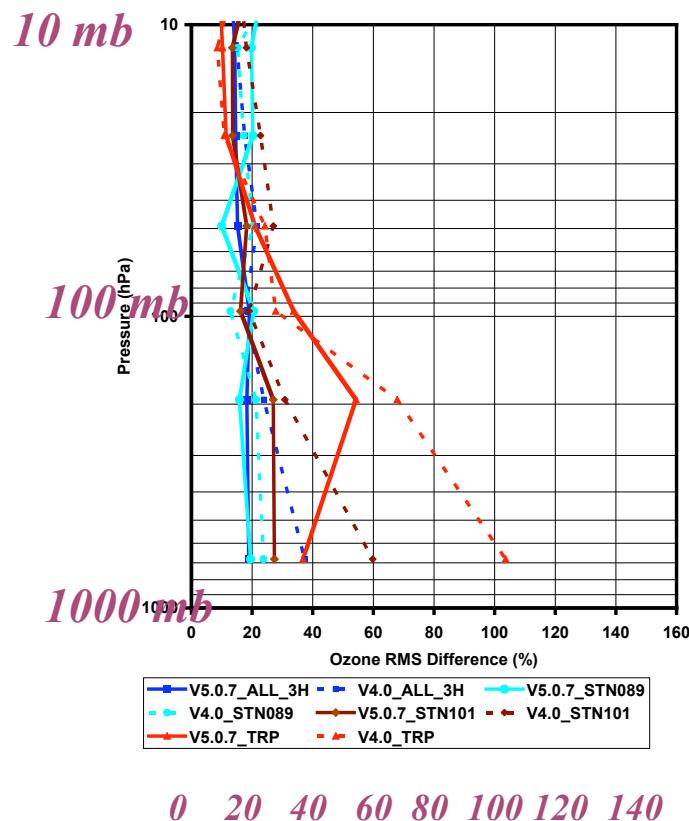
- **Performed validations for V4 and V5**
  - AIRS Retrieved Ozone Profiles with WOUDC O<sub>3</sub>SNDS
- **Results:**
  - **The V5 algorithm significantly improves the retrieval bias and RMS differences for the lower troposphere and especially over the tropical regions.**
    - **Retrieval Improvement for the Lowest Layer (1000-260 mb) is Mainly due to the Climatology First Guess**
  - **The Retrieval Statistics with Global O<sub>3</sub>SNDS**
    - **Bias ~ 5%**
    - **RMS Difference ~ 20%**

# V5 Physical Retrievals - Different Stations

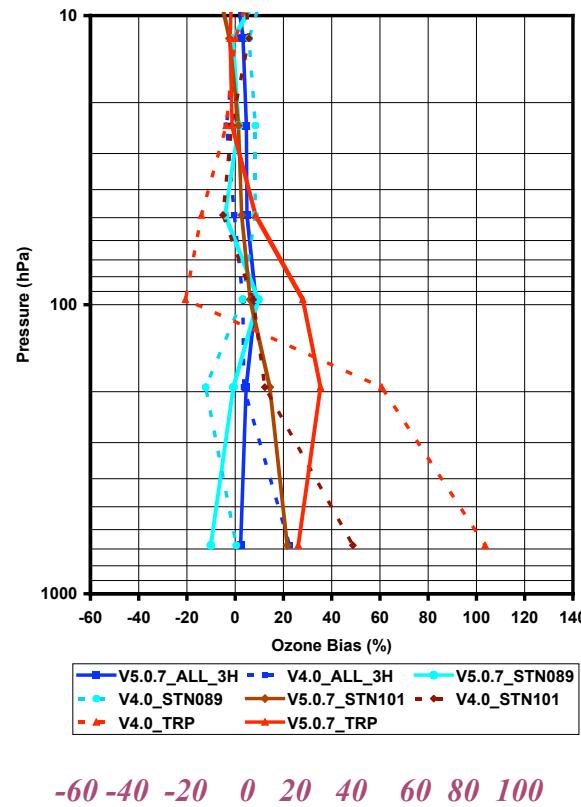
ALL (N=353), STN 089 (N=53, NH),  
STN 101(N=50,SH), Tropics (N=54, ±12HR)



RMS Difference



Bias



V5 Climatology First Guess  
Helps Physical Retrieval for  
the Lowest Layer 1 (1000-  
260 mb)

V4 Dotted lines, V5 Solid Lines  
ALL\_3H STN089 STN101 TRP\_12H ALL\_12H



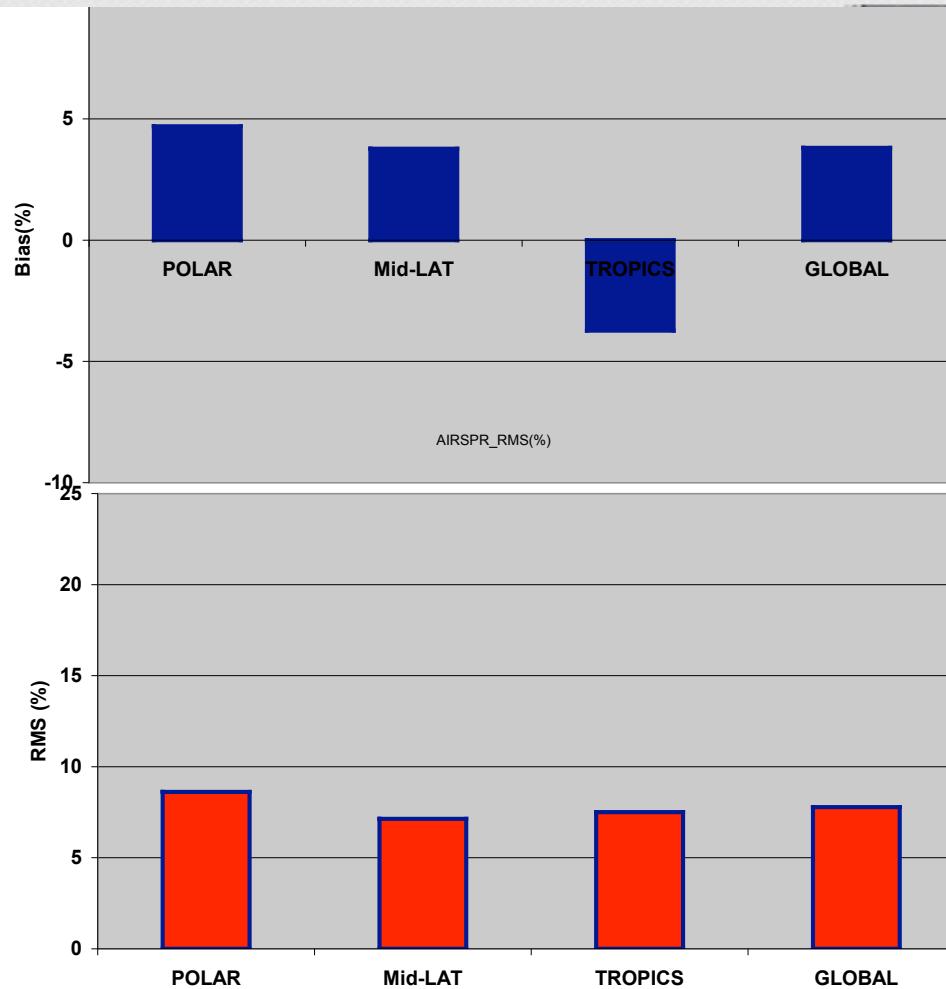
# What We Did and What is Achieved (2)

- Performed Validations for V4 and V5 Total Ozone
  - With WOUDC Brewer/Dobson Station Measurements.
- Results:
  - Total ozone from both the V4 and V5 versions agrees well
    - Bias ~ 4% and an RMS difference ~ 8%.
    - V5 ozone retrievals are better than V4
      - » Over Desert Regions (Due to Improvements in Emissivity Regression implemented in V5)
      - » In Depicting Ozone Hole Events, Trends, Seasonality Patterns etc.
  - However, V5 Algorithm
    1. Slightly underestimates total ozone in the tropics
    2. Slightly overestimates total ozone in the midlatitude and high latitudes regions.
    3. Emissivity retrievals may require further refinements.

# V5 - Total Ozone Statistics with BD Measurements Polar, Mid-Lat, Tropics, and Global



Total Ozone Statistics	Match/Region Day	Polar	Midlat	Tropics	Total
1409	2282	315	4096		



**V5 RMS**

## V5 Physical Retrieval Bias and RMS Difference

Slightly underestimates total ozone in the tropics  
Slightly overestimates total ozone in the midlatitude and polar regions.



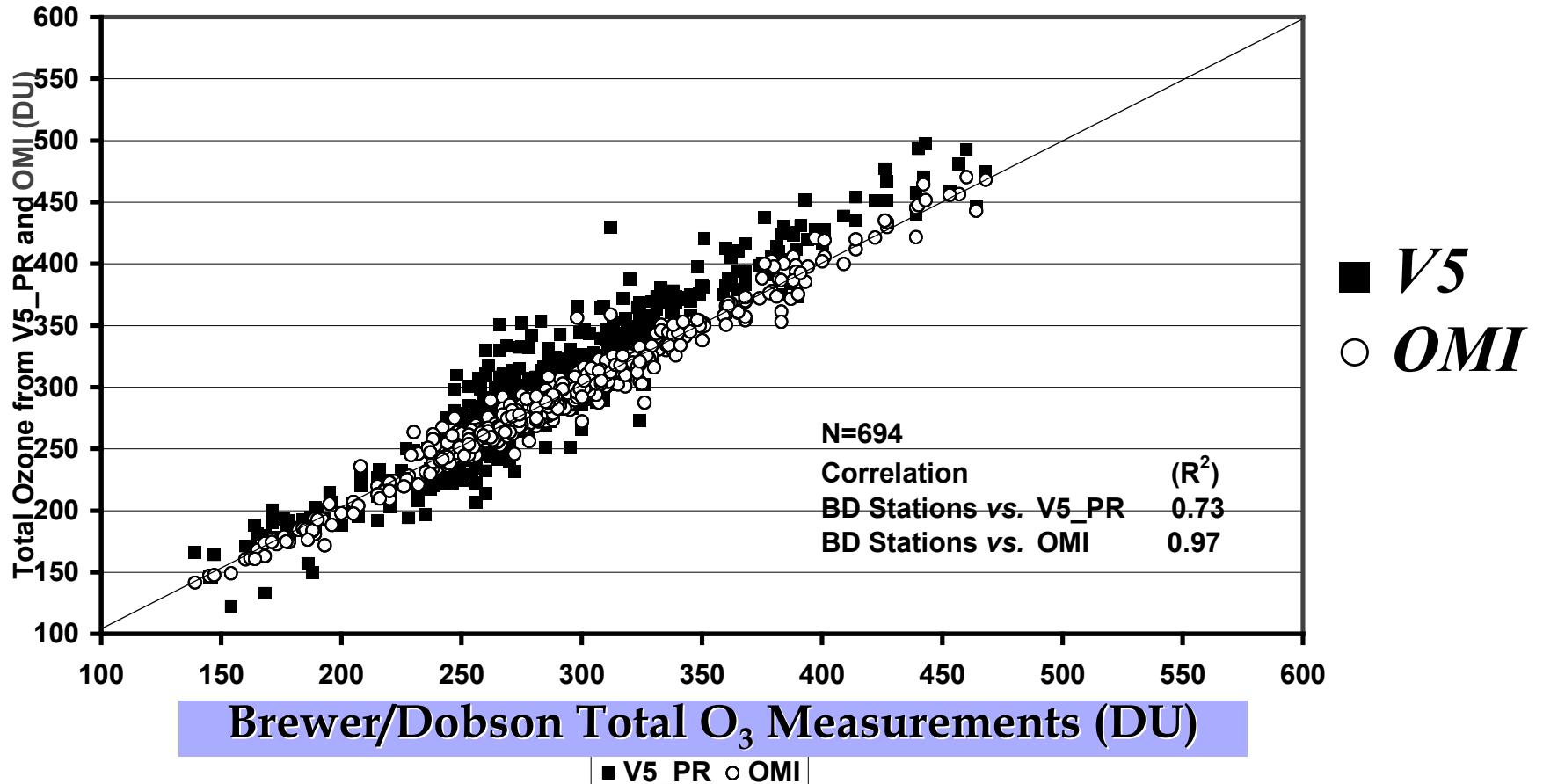
# What We Did and What is Achieved (3)

- **Using Simultaneous AIRS & OMI Observations and BD Total Ozone Measurements**
  - » Relative Performance Assessment of AIRS and OMI Total Ozone Retrievals.
- **Results:**
  - » **The OMI Retrieval Bias**
    - ~ 2-3% for most of the stations
  - » **The AIRS Retrieval bias is ~ 6% for high latitude STNS**
  - » **The AIRS retrieval shows**
    - Slight underestimation in the tropics
    - and a slight overestimation in the high latitudes.
  - » **OMI Data Are Extremely Good and Could be Used as a transfer standard for the truth in Analyzing Global Grids.**

# Simultaneous Measurements of AIRS, OMI and WOUDC BD Measurements.



AIRS\_PR Aura-OMI



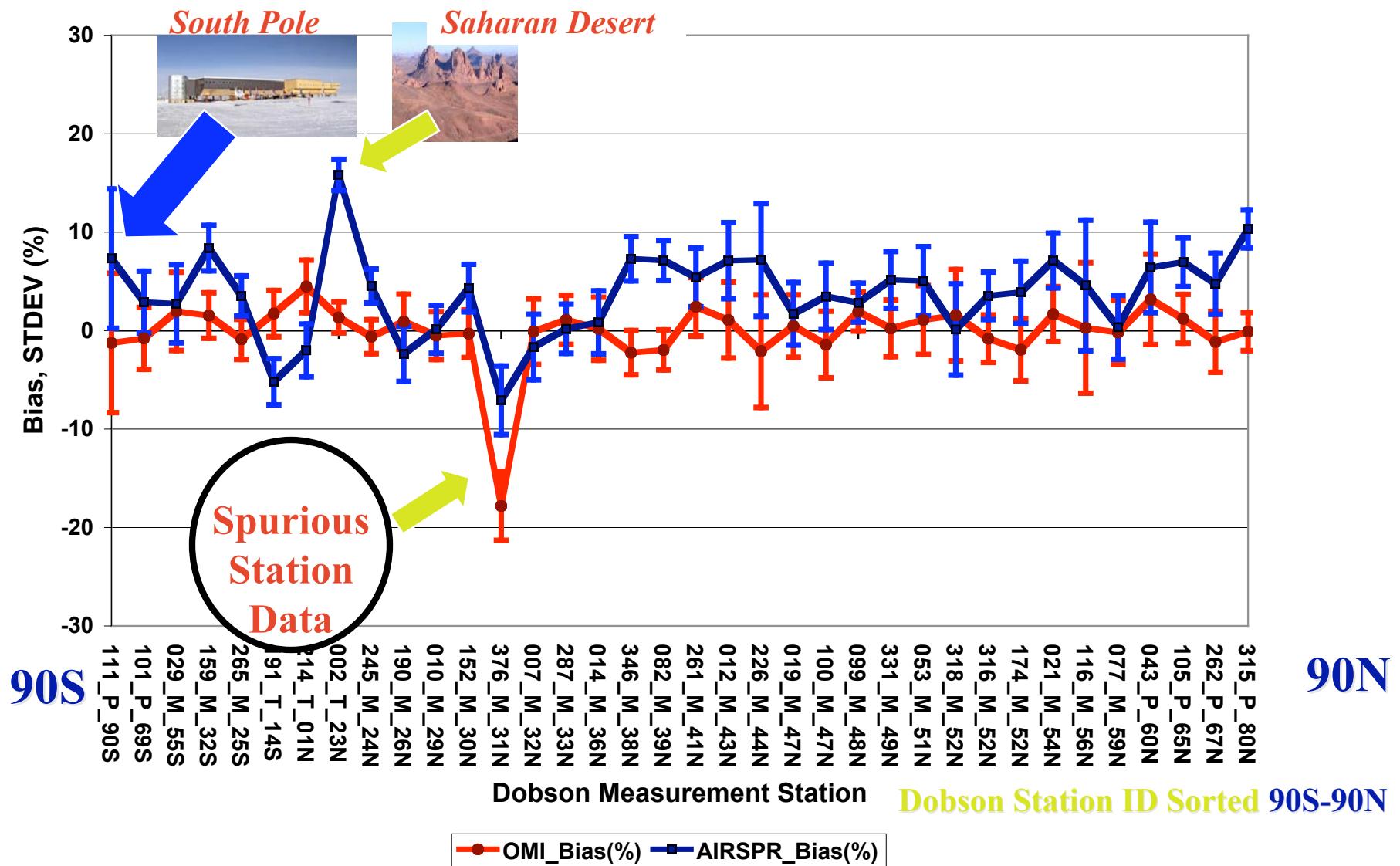
*OMI: 15 km resolution, Overpass retrievals collocated within 25 km (CT Pixel)*

*AIRS : 50 km resolution, collocated within 100 km distance to BD Measurements*

*Intent: Just to get a feel for the OMI, and see whether OMI global grids could be used as a transfer standard for the truth in analyzing AIRS global grids*

# Total Ozone – Percent Bias

## V5 RET vs. BD STNS; OMI vs. BD STNs.





## What We Did and What is Achieved (4)

- Analyzed two years (2004-2005) of AIRS V4 and V5 Ozone profile Retrievals for Characteristic Features/Trends
- Results:
  - » The AIRS V5 ozone profiles
    - » Show the ozone hole events clearly
    - » Depicts Brewer/Dobson circulation patterns as expected.



# AIRS V5 Clearly Depicts Ozone Hole

V4 09/2004

Ozone, Ascending, AIRS V4  
(Period: 01Sep2004–30Sep2004)

10 mb  
100 mb  
1000 mb

-90S      Latitude      90N

NOAA/NESDIS/STAR/SMCD/SPB/IOSSPD

(Period: 01Sep2005–30Sep2005) 2007-05-08 11:55

10 mb  
100 mb  
1000 mb

V4 09/2005

NOAA/NESDIS/STAR/SMCD/SPB/IOSSPD

2007-05-08 11:55

V5 09/2004

Ozone, Ascending, AIRS V5  
(Period: 01Sep2004–30Sep2004)

10 mb  
100 mb  
1000 mb

-90S      Latitude      90N

Ozone, Ascending, AIRS V5  
(Period: 01Sep2005–30Sep2005)

10 mb  
100 mb  
1000 mb

V5 09/2005

NOAA/NESDIS/STAR/SMCD/SPB/IOSSPD

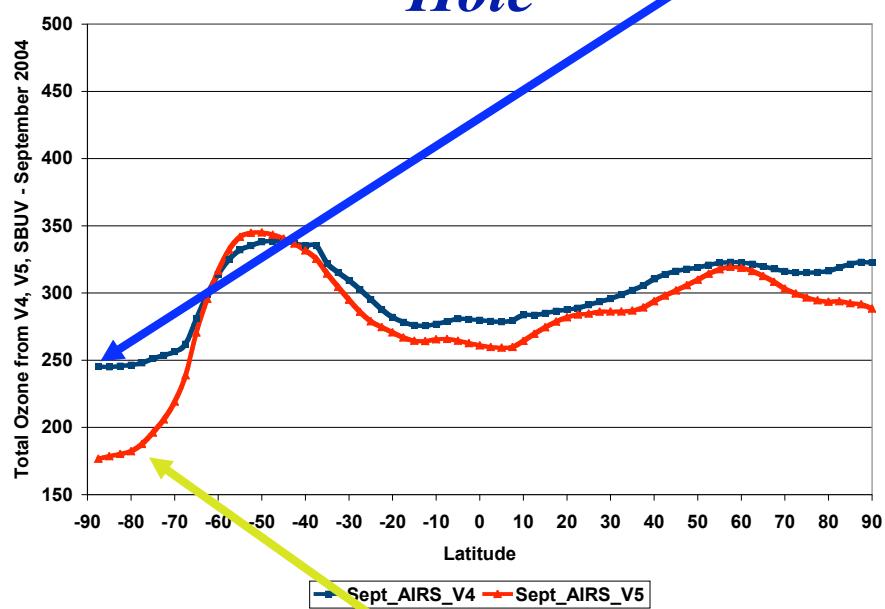
2007-05-08 10:37

# V4, V5 Total Ozone - September 2004-2005



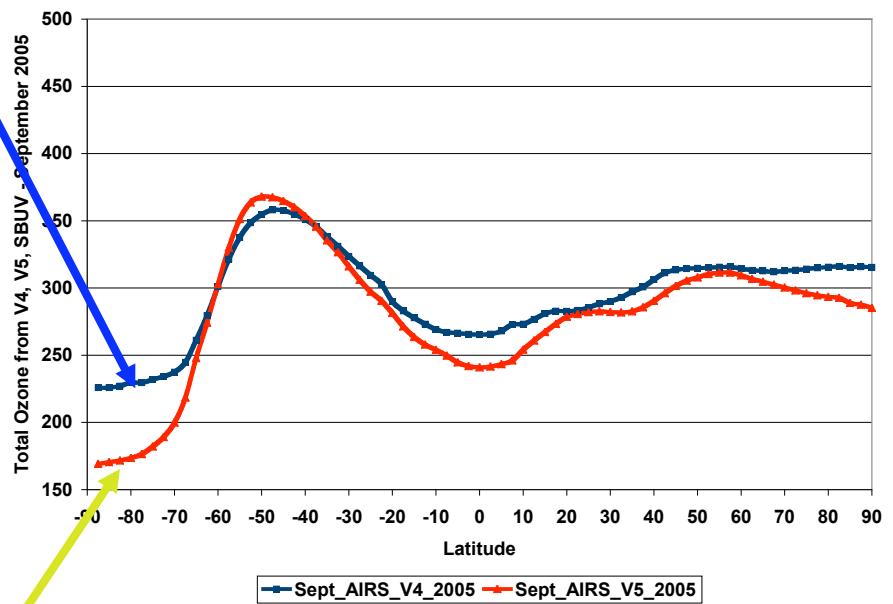
## 2.5° Zonal Averages

Sep. 2004



*V4 has difficulty Depicting Ozone Hole*

Sep. 2005



*V5 Depicts Ozone Hole Clearly*

# BD Circulation Features As Seen with AIRS V5 Monthly Averages of O<sub>3</sub> Profile Latitude vs. Pressure



V5 10/2004

V5 12/2004

V5 03/2005

Ozone, Ascending, AIRS V5  
(Period: 01Oct2004–31Oct2004)

Ozone, Ascending, AIRS V5  
(Period: 01Dec2004–31Dec2004)

Ozone, Ascending, AIRS V5  
(Period: 01Mar2005–31Mar2005)

10 mb

100 mb

1000 mb

NOAA/NESDIS/STAR/SMCD/SPB/IOSPPDT

Pressure (mb)

1000

100

2007– NOAA/NESDIS/STAR/SMCD/SPB/IOSPPDT

Pressure (mb)

1000

100

2007–05–08 09:3.

Pressure (mb)

Ozone, Ascending, AIRS V5  
(Period: 01Jun2005–30Jun2005)

10 mb

100 mb

1000 mb

NOAA/NESDIS/STAR/SMCD/SPB/IOSPPDT

Pressure (mb)

1000

100

2007– NOAA/NESDIS/STAR/SMCD/SPB/IOSPPDT

Pressure (mb)

1000

100

2007–05–08 10:3.

2007–05–08 10:10

V5 10/2005

V5 08/2005

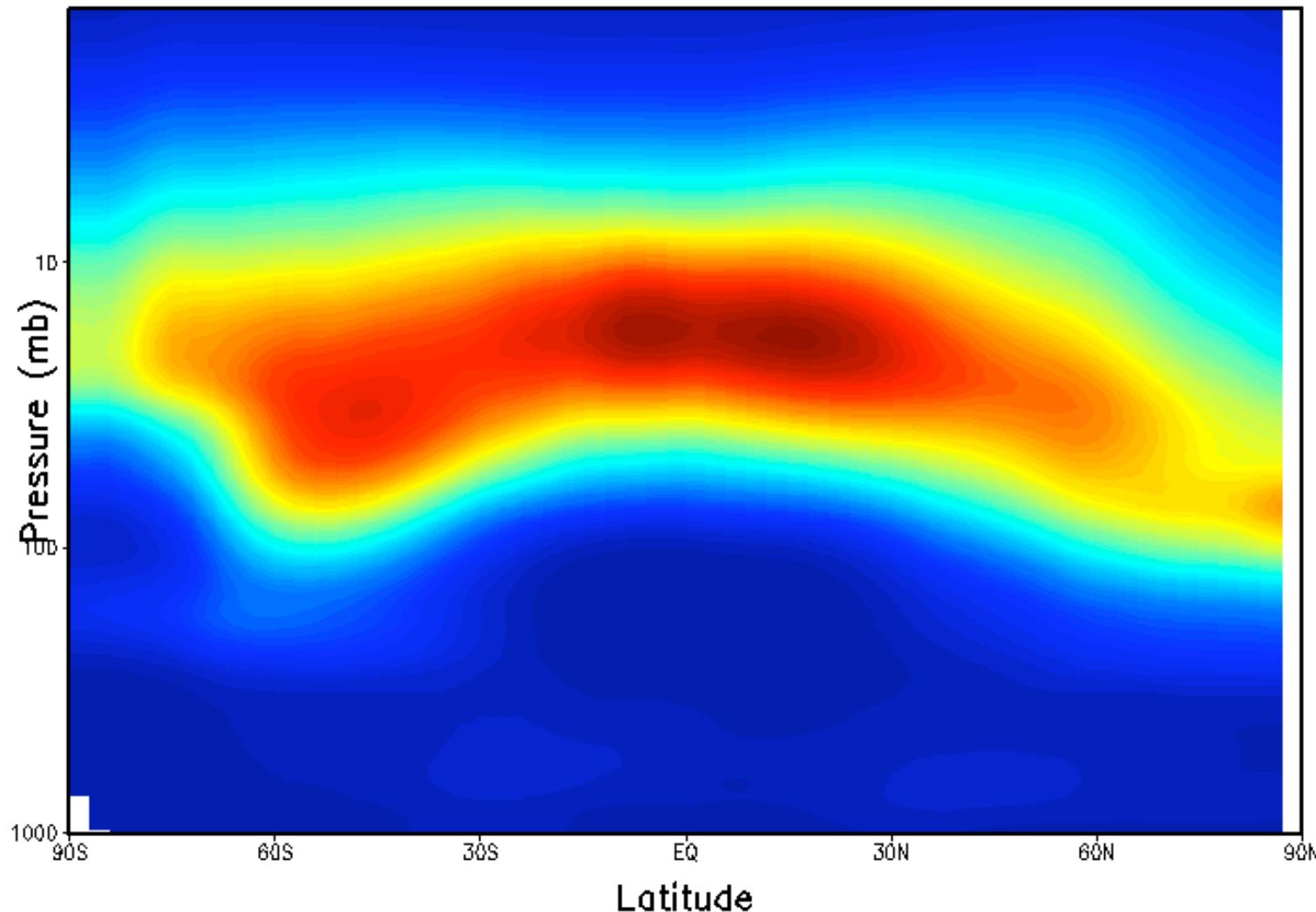
V5 06/2005

We can generate these maps for each day – next slide is a movie loop with 15-day maps.  
INTL S/STE

# AIRS V5 BD Circulation MOVIE LOOP



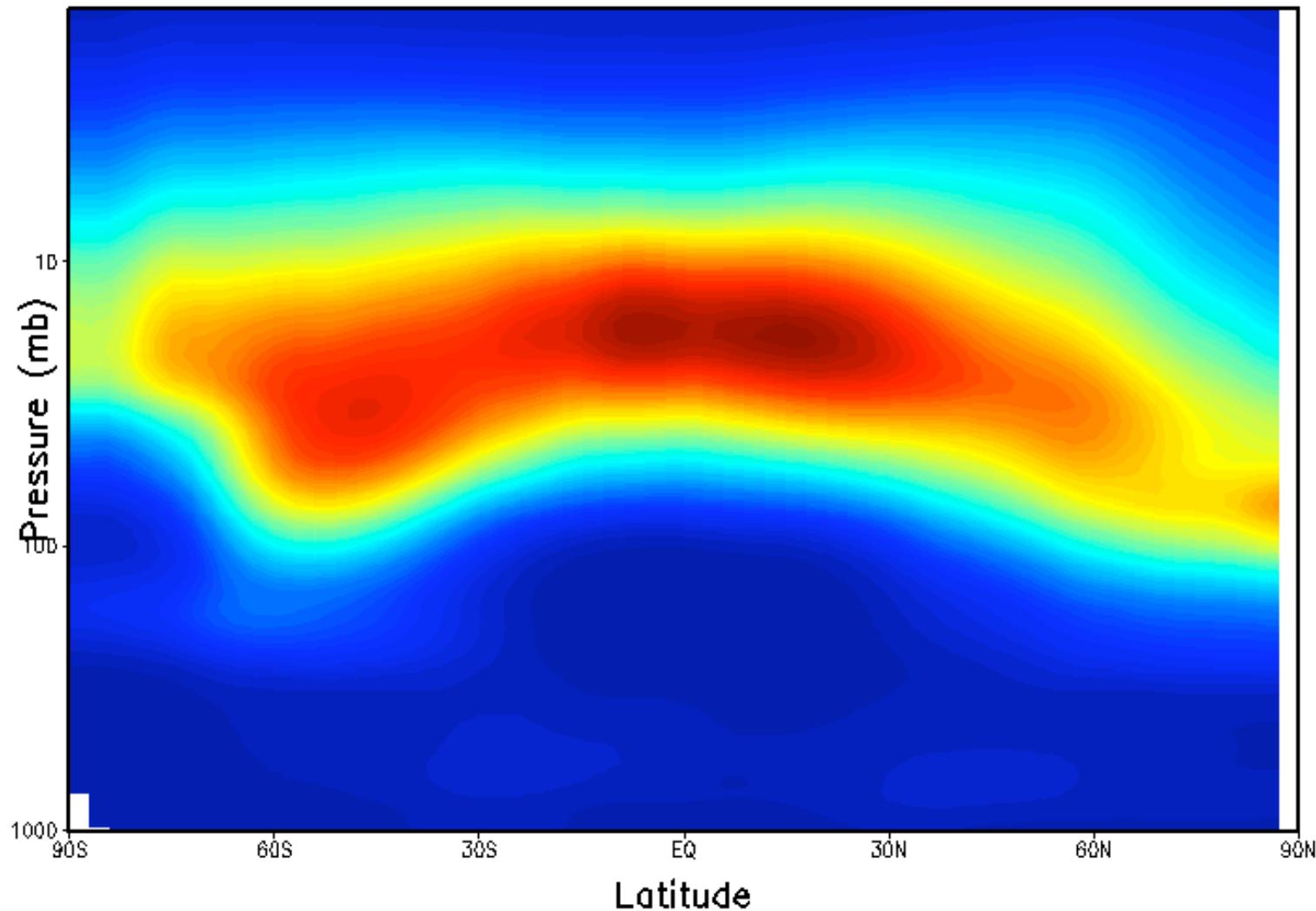
Ozone, Ascending, AIRS V5  
(Period: 01Oct2004–15Oct2004)



# AIRS V5 BD Circulation MOVIE LOOP



Ozone, Ascending, AIRS V5  
(Period: 01Oct2004–15Oct2004)





# What We Did and What is Achieved (5)

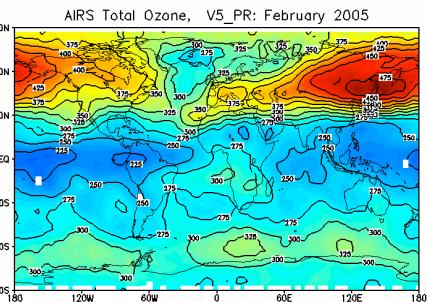
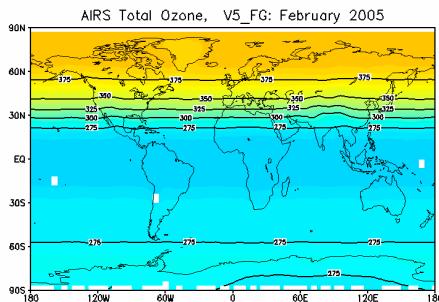
- **Analyzed Global Monthly Maps of AIRS total ozone with the OMI and SBUV maps:**
  - To evaluate the ability of the AIRS retrievals in reproducing the characteristic trends and seasonal cycles as depicted by the OMI and SBUV instruments.
- **Results:**
  - » Analysis of two years (2004-2005) of V5 total ozone retrievals reveal:
    - The AIRS V5 retrieval shows trends and patterns in concurrence with the OMI (for 2005) and SBUV depictions.
    - The AIRS retrieval shows a tendency
      - Slight underestimation in the tropics
      - Slight overestimation in the high latitudes.

# Total Ozone - February 2005

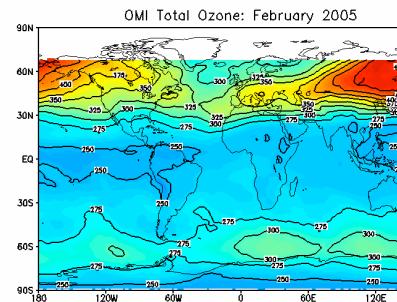
## AIRS V4,V5-PR, OMI, SBUV, and GFS



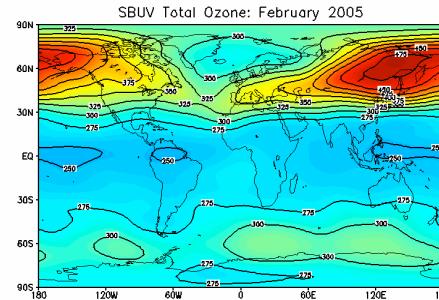
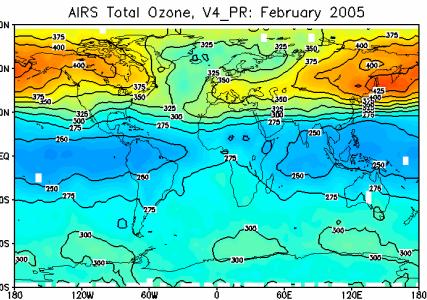
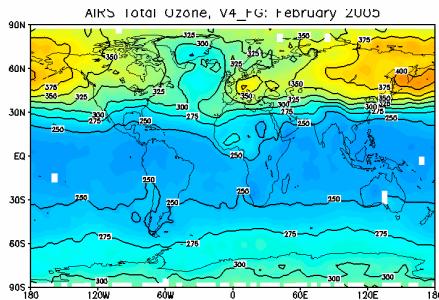
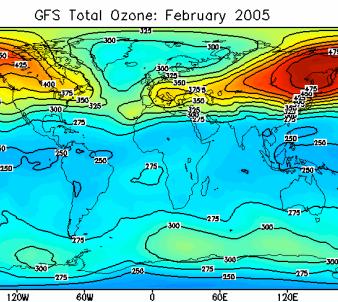
**V5-FG  
Climatology**



**OMI**



**GFS**



**V4-PR**

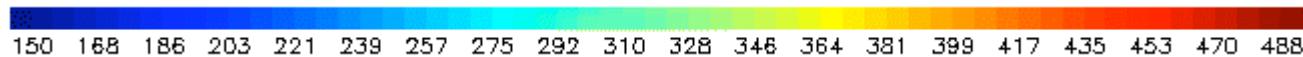
**SBUV**

**V4-FG  
(Regression)**

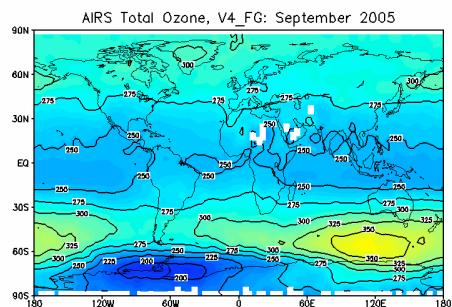
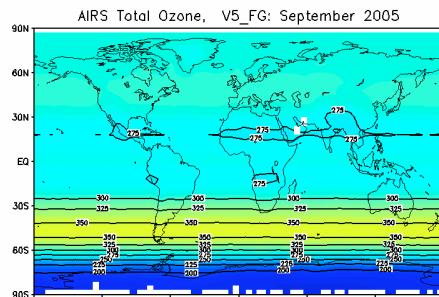
ECMWF Training for  $T(p)$ ,  $q(p)$  regression is good, (because ECMWF uses RAOB  $T(p)$ ,  $q(p)$  in its analysis) but what about O3SNDS (?). NCEP-GFS Assimilates SBUV Ozone profiles (better choice ? Or O3SNDS ?)

# Total Ozone - September 2005

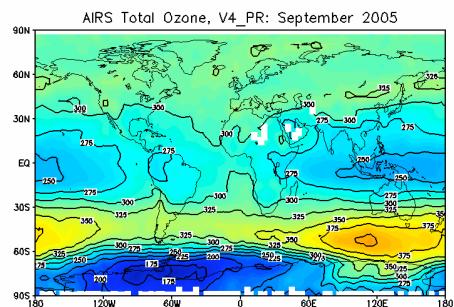
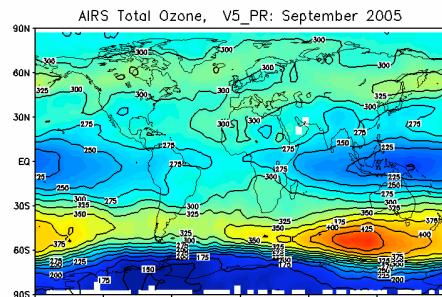
## AIRS V4, V5-PR, OMI, SBUV, and GFS



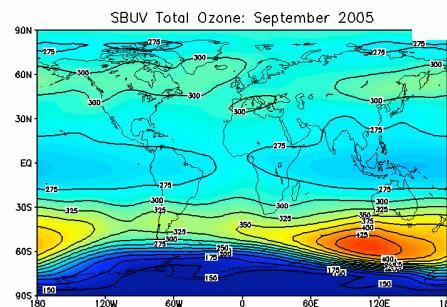
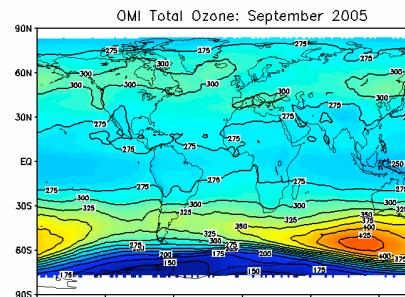
**V5-FG  
Climatology**



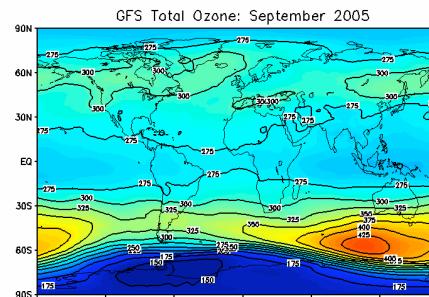
**V5-PR**



**OMI**



**GFS**



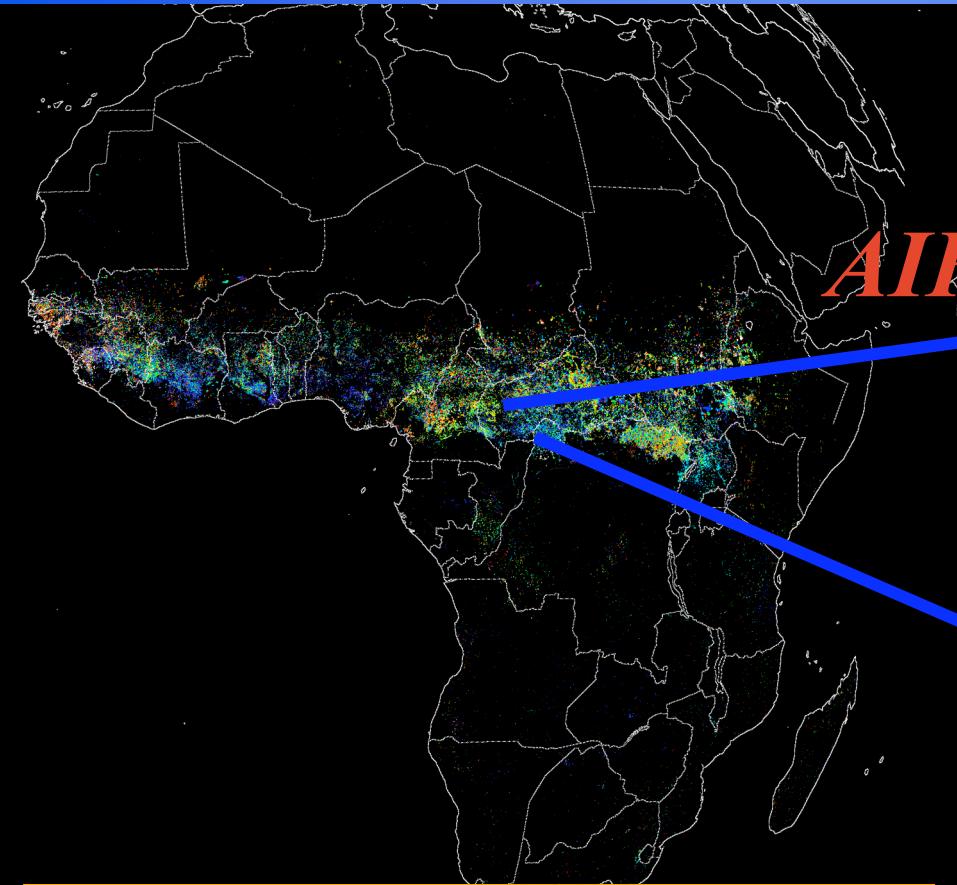
**V4-FG  
(Regression)**

**V4-PR**

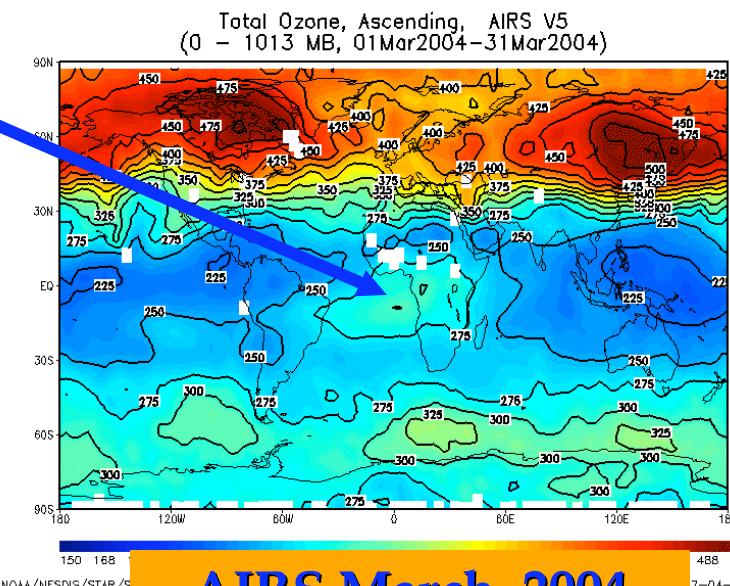
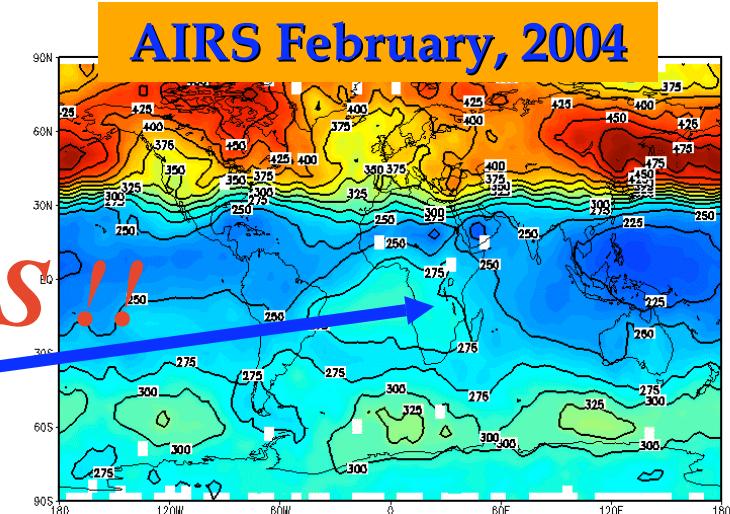
**SBUV**

*Training data for FG Reg. should adequately represent Ozone hole events and other strategic locations*

# Biomass Burning Related Ozone Changes Seen by AIRS?



February, 2004  
SEVERI Derived Map of Active  
Fire Detections (AGU, Gareth  
Roberts)



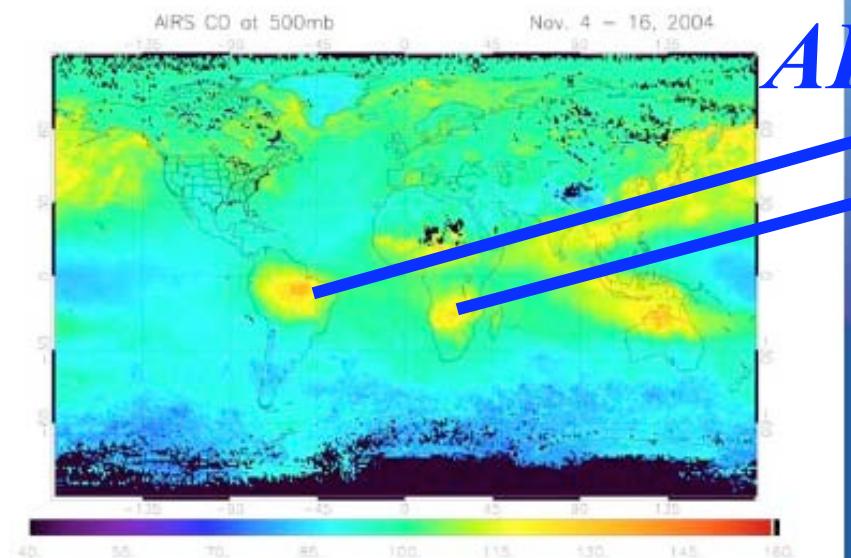
150 168 488  
NOAA/NESDIS/STAR/S 7-04-23 16:12

AIRS March, 2004

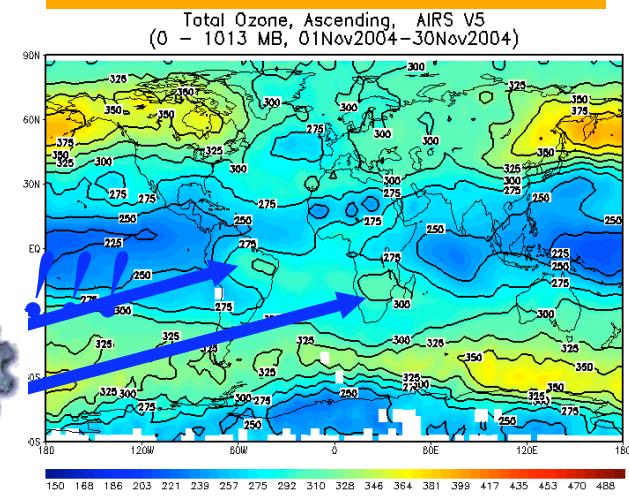


# Biomass Burning Related Ozone Changes Seen by AIRS?

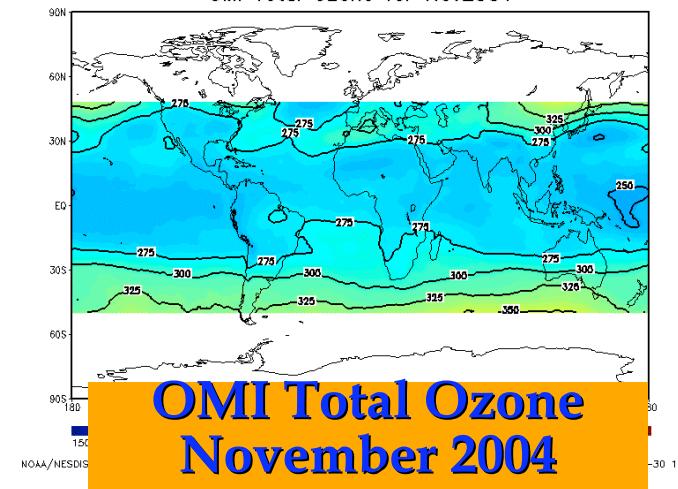
MODIS Fire Counts  
November 2004,  
Kevin Bowman, JPL



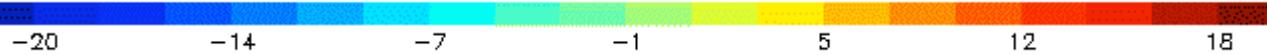
AIRS Total Ozone  
November 2004



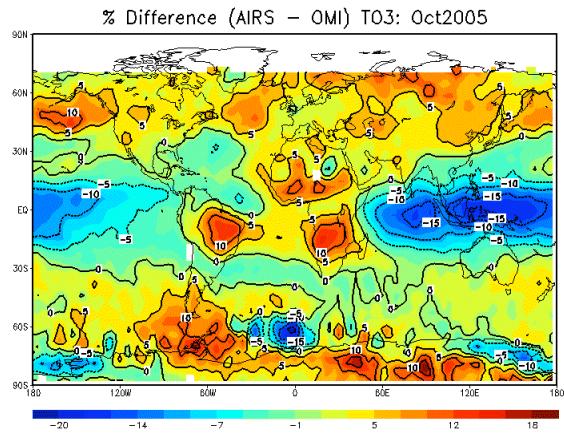
OMI Total Ozone for Nov2004



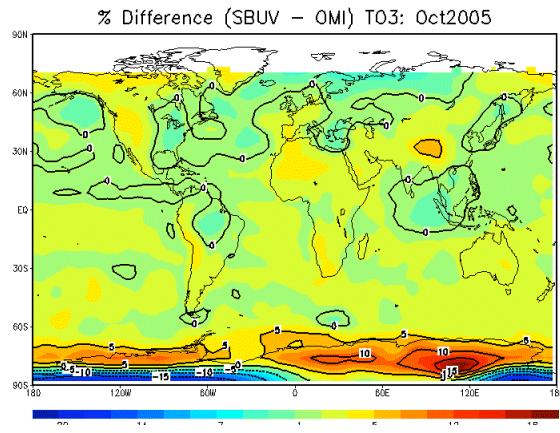
# Total Ozone Difference Maps (%) (AIRS\_V5 - OMI)/OMI; (SBUV-OMI)/OMI; (GFS-OMI)/OMI



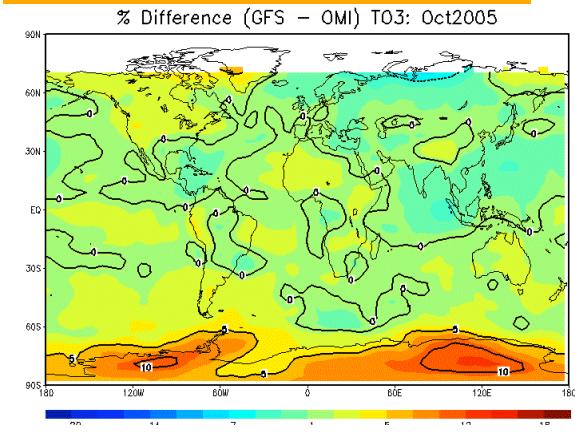
**AIRS-OMI 10/2005**



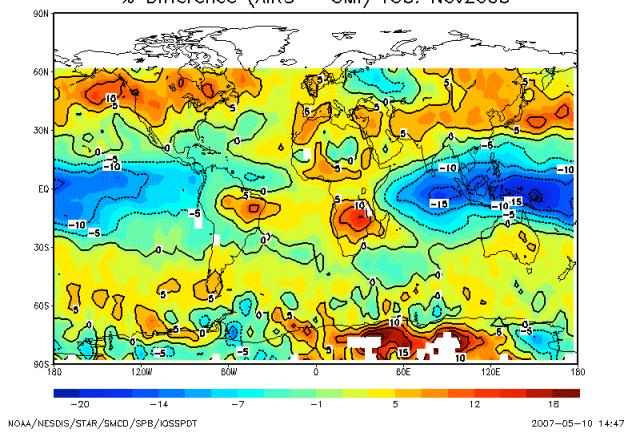
**SBUV-OMI 10/2005**



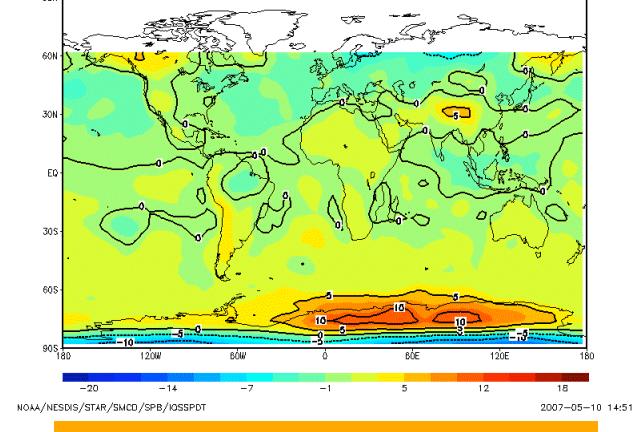
**GFS-OMI 10/2005**



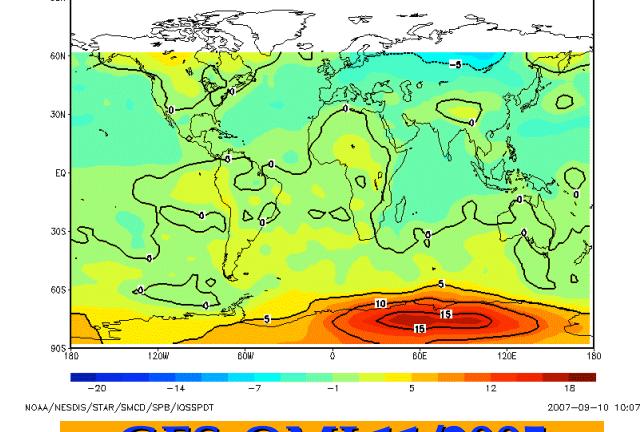
**AIRS-OMI 11/2005**



**SBUV-OMI 11/2005**



**GFS-OMI 11/2005**



**AIRS-OMI 11/2005**

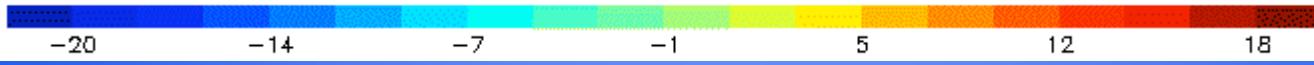
**SBUV-OMI 11/2005**

**GFS-OMI 11/2005**

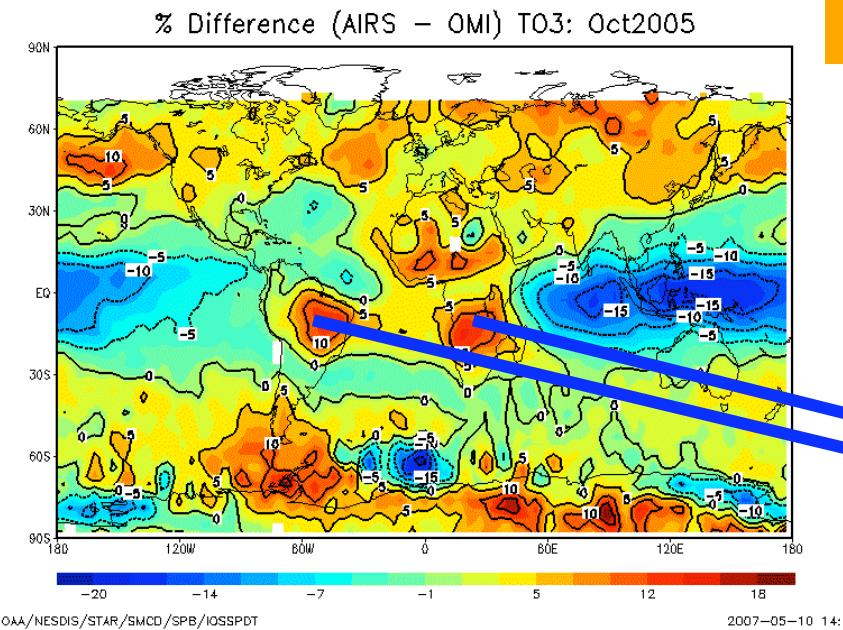
Characteristics Invisible (or Slightly Visible) to Other Instruments are  
Visible to AIRS (Hope they are not Artifacts)



# Total Ozone Difference Map (AIRS\_V5 - OMI)/OMI)

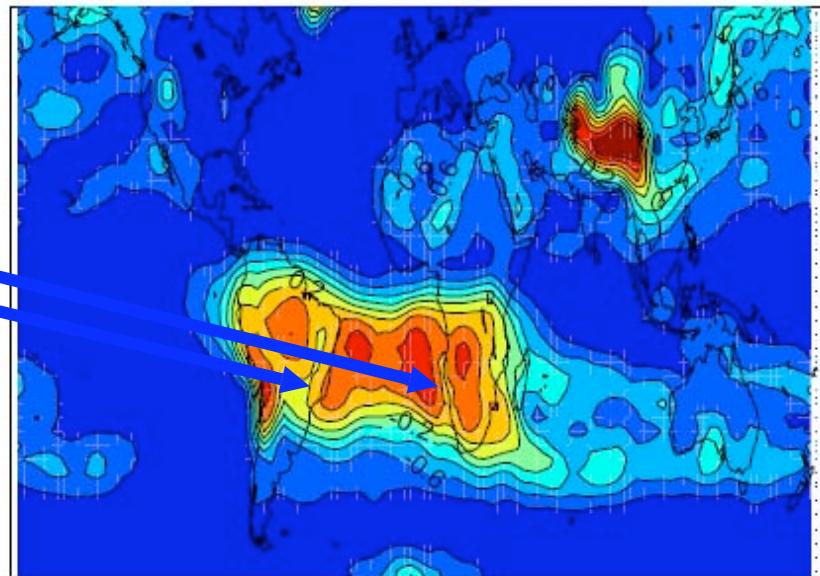


AIRS-OMI 10/2005

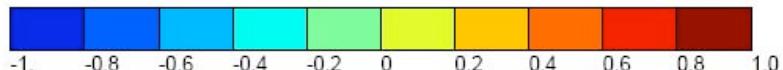


CO-Ozone and Biomass Burning

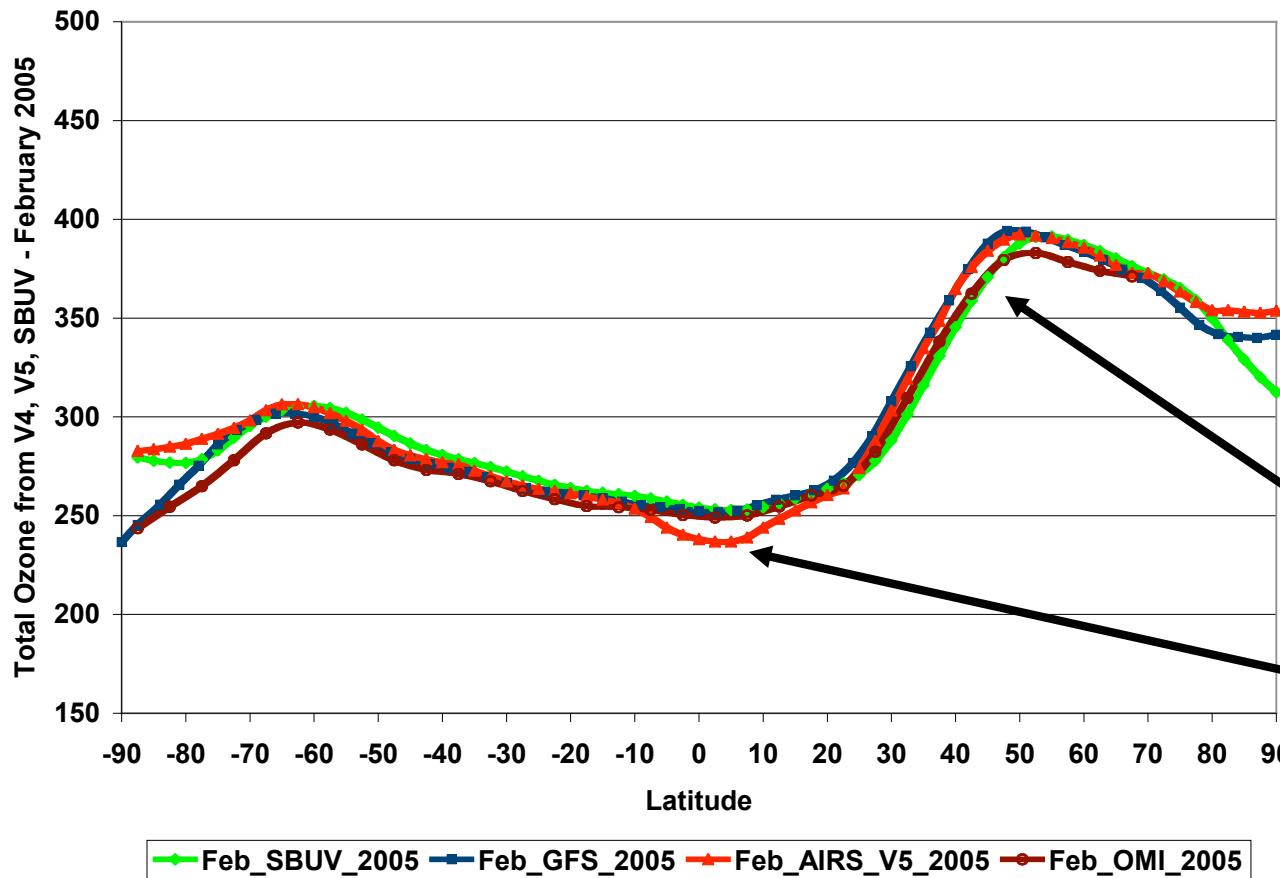
R Coeff, 200510



CO-Ozone Correlations  
(by Jennifer Wei)



# Total Ozone February 2005 AIRS-V5 (PR), OMI, SBUV, and GFS



February  
2.5° Bins

AIRS V5  
Higher than OMI  
in HighLAT

Lower than OMI  
in the Tropics

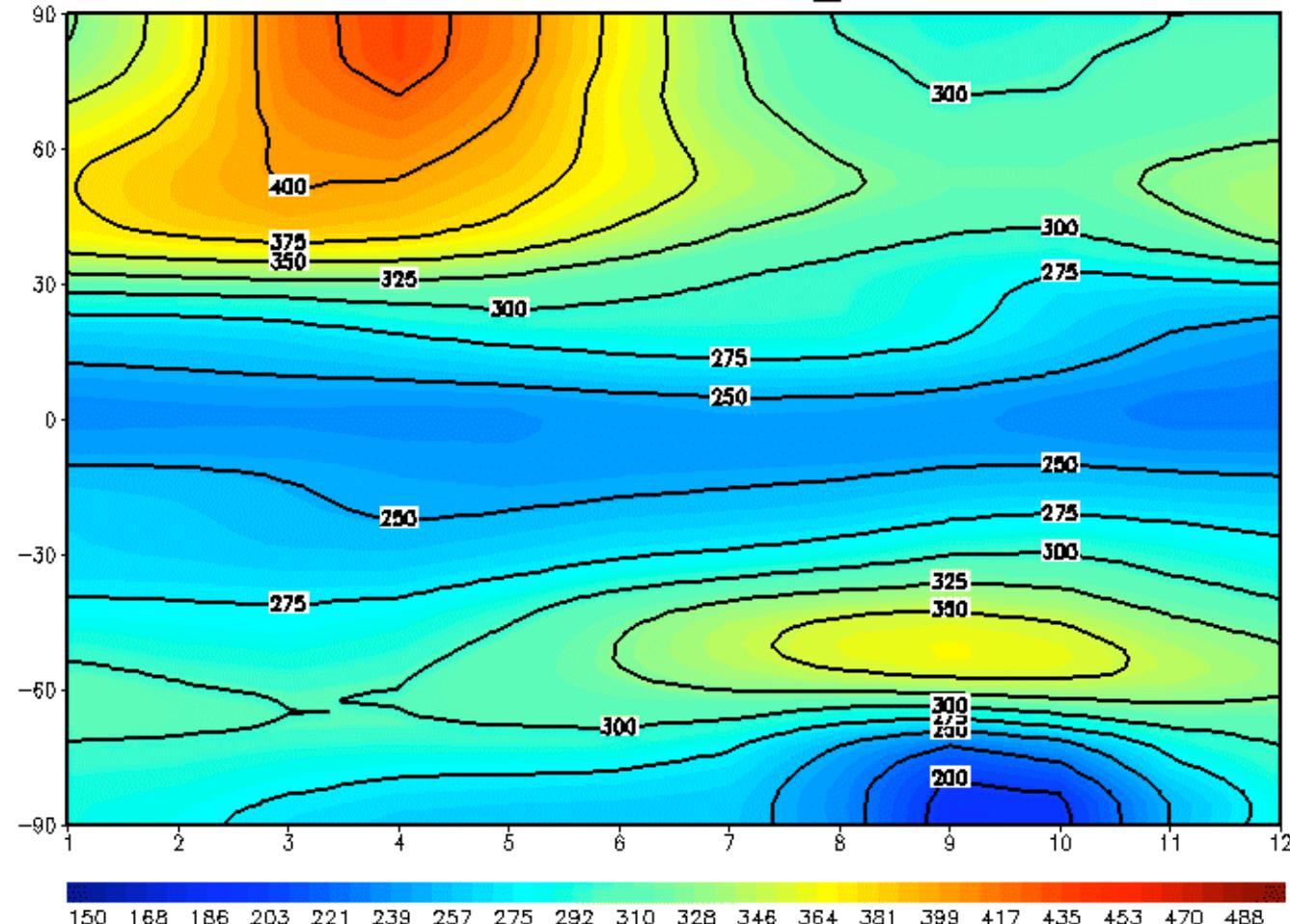
SBUV and OMI  
Match Well

We analyzed 2 years of zonal averages to make conclusion about OMI and AIRS  
Let me know if you wish to see off-line.

# Annual Cycle 2005 AIRS-V5



Total Ozone from AIRS\_V5 2005



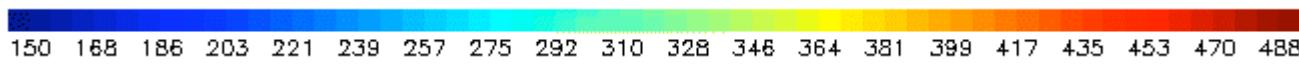
NOAA/NESDIS/STAR/SMCD/SPB/IOSSPDT

*Months 1-12*

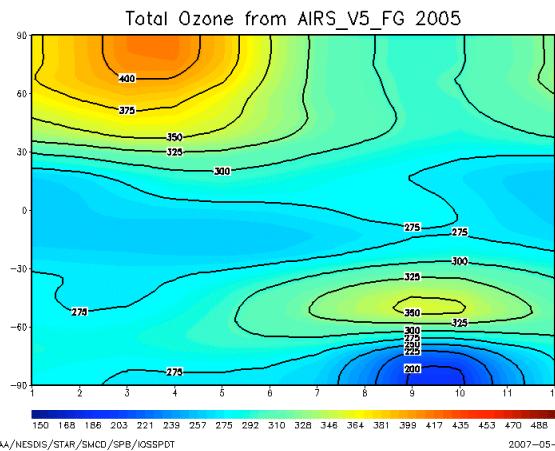
2007-04-25 15:50

150 168 186 203 221 239 257 275 292 310 328 346 364 381 399 417 435 453 470 488

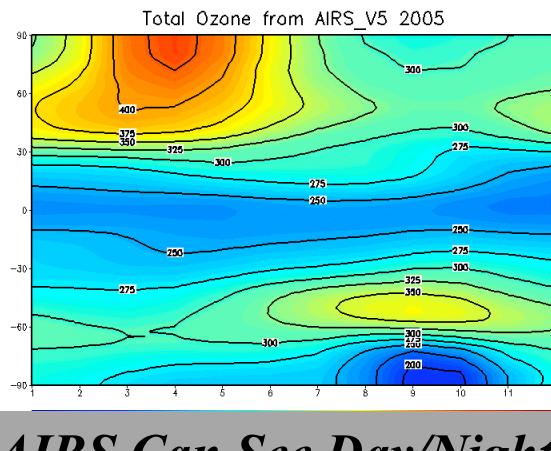
# AIRS V4, V5 (PR and FG) OMI, SBUV 2005 Annual Cycle



**AIRS-V5 FG**

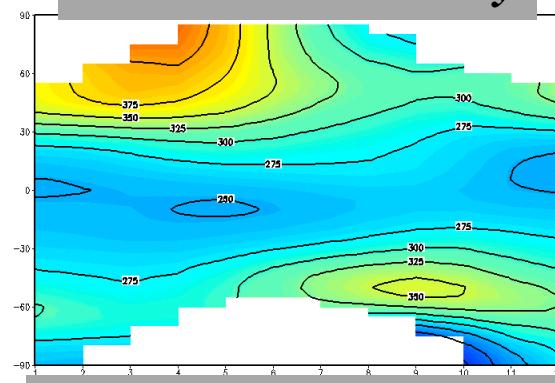


**AIRS-V5 RET**



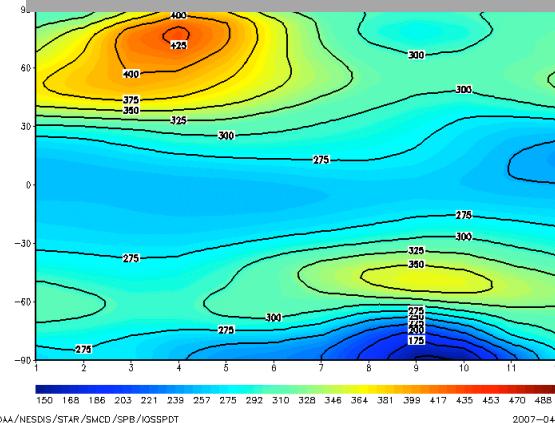
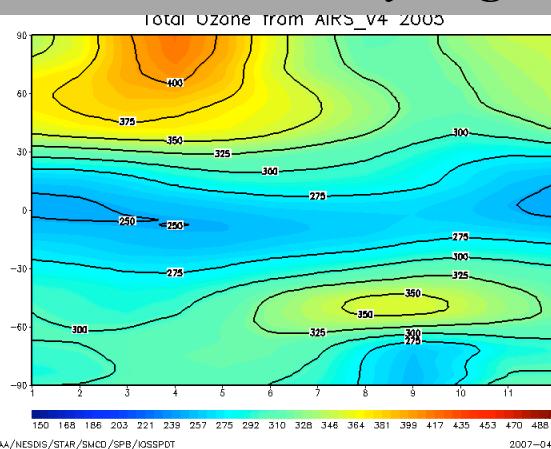
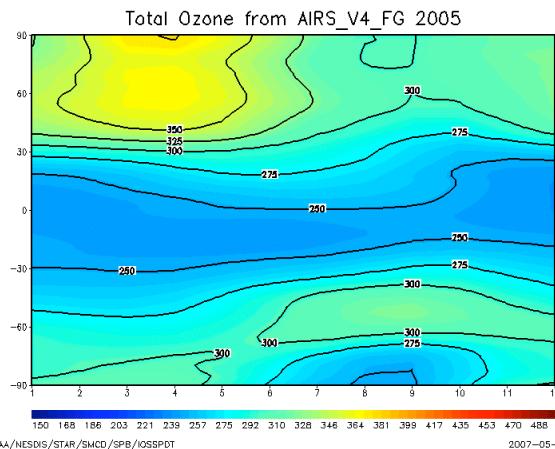
**OMI 2005**

*Sun-Lit Portions Only*



*AIRS Can See Day/Night*

*SBUV Appended with GFS Beyond 80 Degrees.*



**AIRS-V4 FG**

**AIRS-V4 RET**

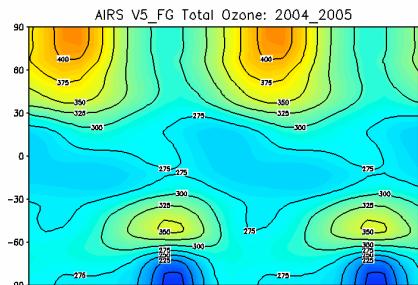
**SBUV 2005**

# Total Ozone Annual Cycle for 2 Years (2004-2005) AIRS V4, V5-PR, OMI, SBUV, and GFS

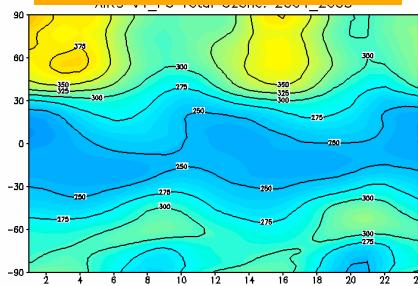


150 168 186 203 221 239 257 275 292 310 328 346 364 381 399 417 435 453 470 488

**V5-FG  
Climatology**

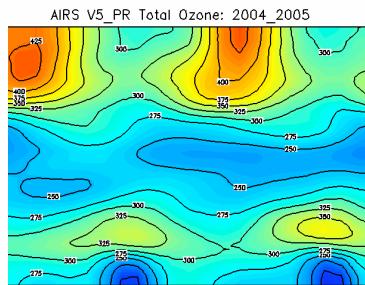


Months 1-24

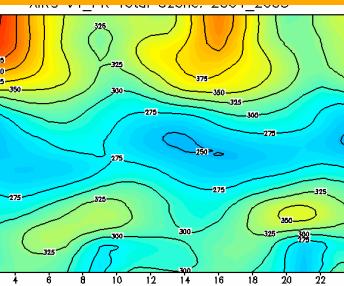


**V4-FG  
(Regression)**

**V5-PR**

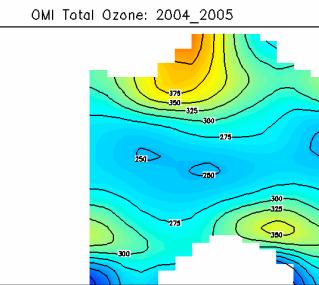


Months 1-24

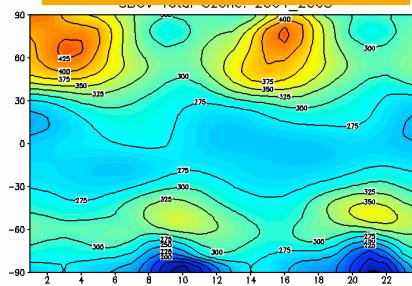


**V4-PR**

**OMI**

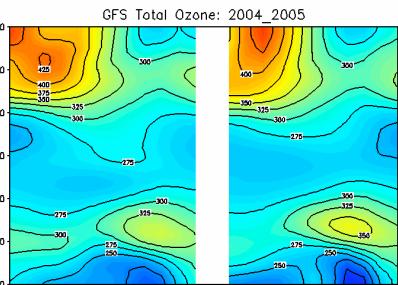


Months 1-24



**SBUV**

**GFS**



Months 1-24

Annual Cycle for 2 Years (2004-2005)  
with 2.5 Degree Zonal Averages



**Q: Whether the AIRS Instrument Measures Ozone Profiles and Total Ozone Reasonably ? YES.**

## **V5 Algorithm**

- **Retrieval is Solely Due to Channel Radiances**
- **Ability to Capture Trends and Seasonal Patterns**
- **Reasons for Deficiencies are Understandable and Remedies can be implemented.**
- Improvements
  - **Algorithm Optimization**
  - **Playing with Damping Factor and Channel Selection**
  - **Further Emissivity Upgrades are Welcome**
  - **Consistent Positive Bias for High Latitude Regions – Possibly Due to Static Radiance Bias Corrections (Tuning Coefficients)**

## **V4 Algorithm**

- **Good for its time -  $T(p), q(p)$  REG with ECMWF is good, but not for  $O_3(p)$**
- **First Guess Regression Improvements - Proper Training ( $O_3$ SNDs ?) (If we Wish to Continue)**



# Outlook into Near-Future

- **Development of a IASI / T(p), q(p), O<sub>3</sub>(p) Validation System (IASI vs. RAOBs; AIRS vs. RAOBs)**
  - AIRS First Guess with RAOB/O<sub>3</sub>SND Regression for T(p), q(p) and O<sub>3</sub>(p) (Attempted Earlier with Success)
  - Metrics for Validation
- **Synergetic Use of A-Train Products (Aqua, Aura, NOAA-18 (With reference to Ozone))**
  - » **Validation and Inter-comparison with a Same Set of Qualified Measurements (O3SNDs) for Relative Performance Assessment**
  - » **Generation of New Products**
    - Visualize Integrated Observing System Products
      - **Generate Merged Products - AIRS Retrievals, Aura OMI; NOAA-SBUV/2**



# Backup Slides

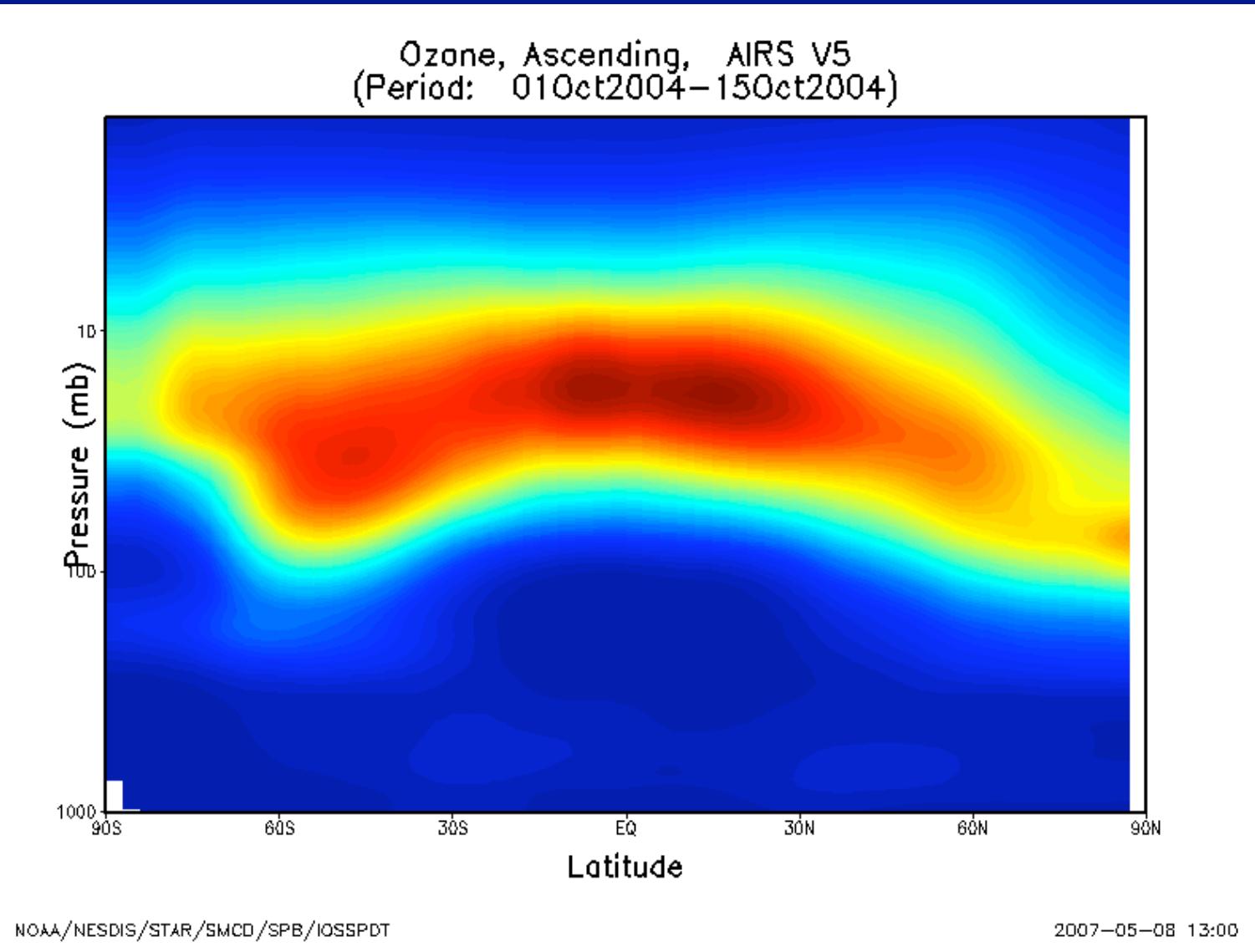
Thank You All for your Patience

The NOAA AIRS Team at The  
Integrated Observing System Science  
And Product Development Team (IOSSPDT)

NOAA/NESDIS Camp Spring, MD, USA

The contents are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of the NOAA, NASA, or the U.S. Government.

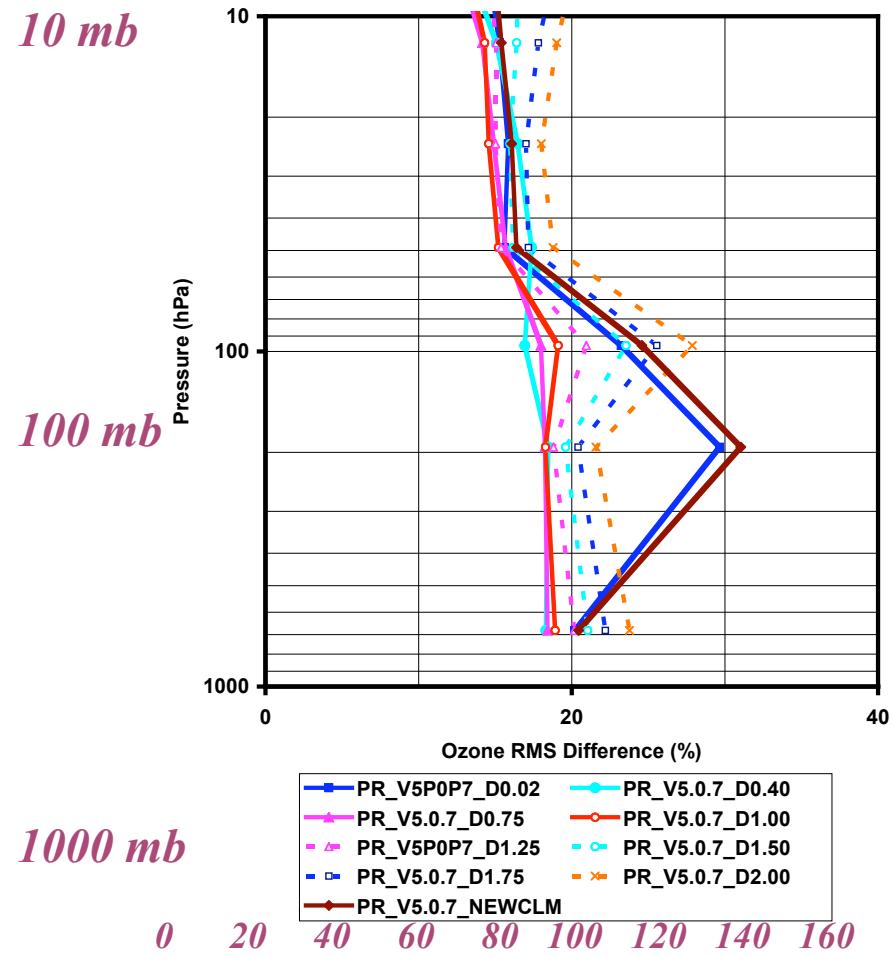
# AIRS Ozone Retrieval ? Reliable Improvements/Remedies Possible ? YES



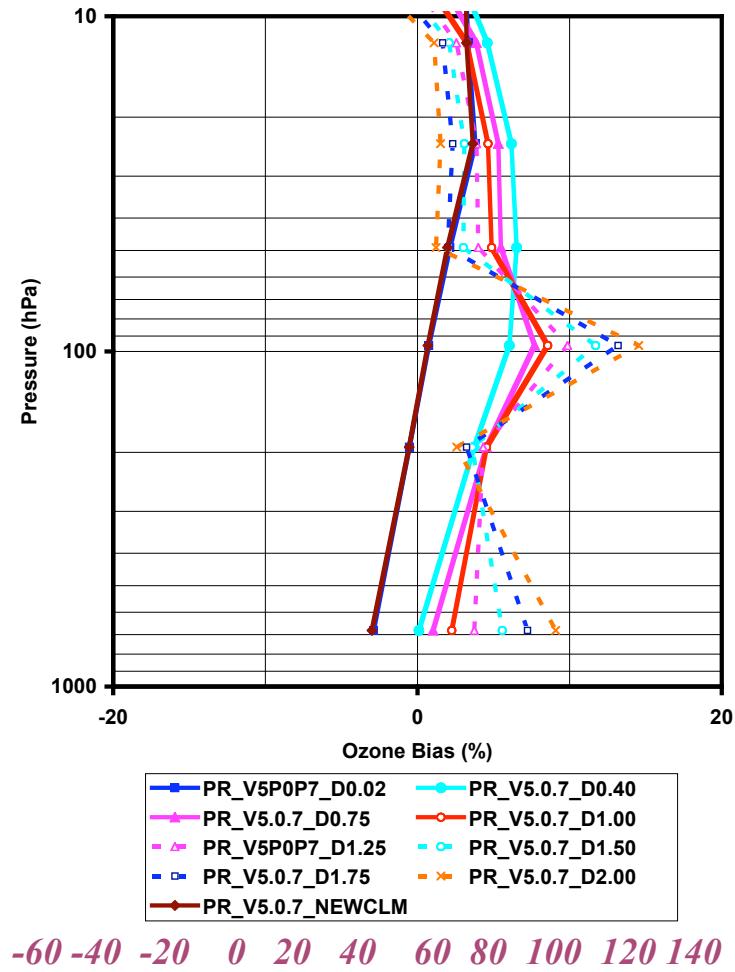
# O3WGT Version 5.0.7 (set 48\_49.xls)



RMS Difference



Bias

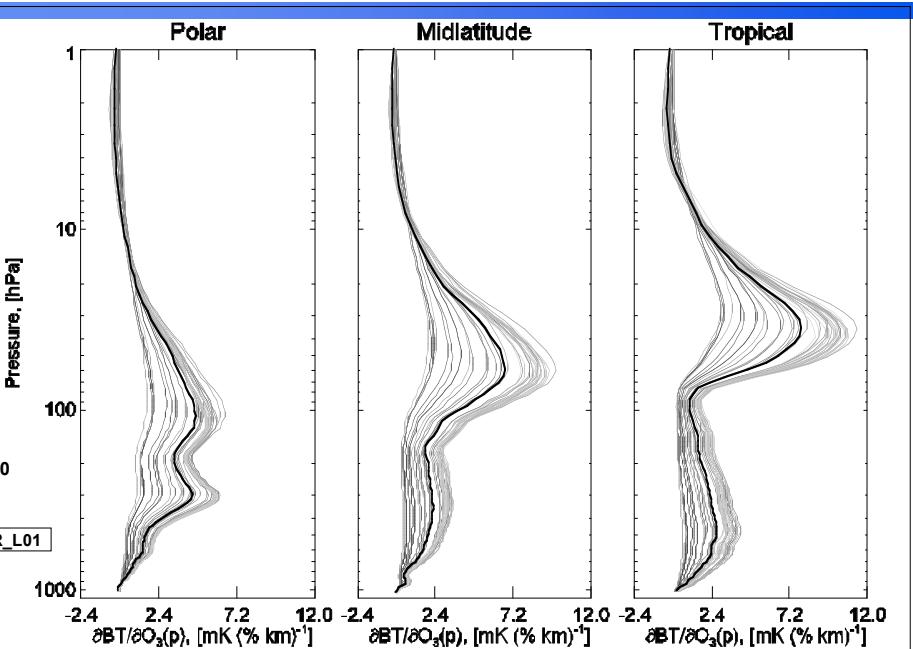
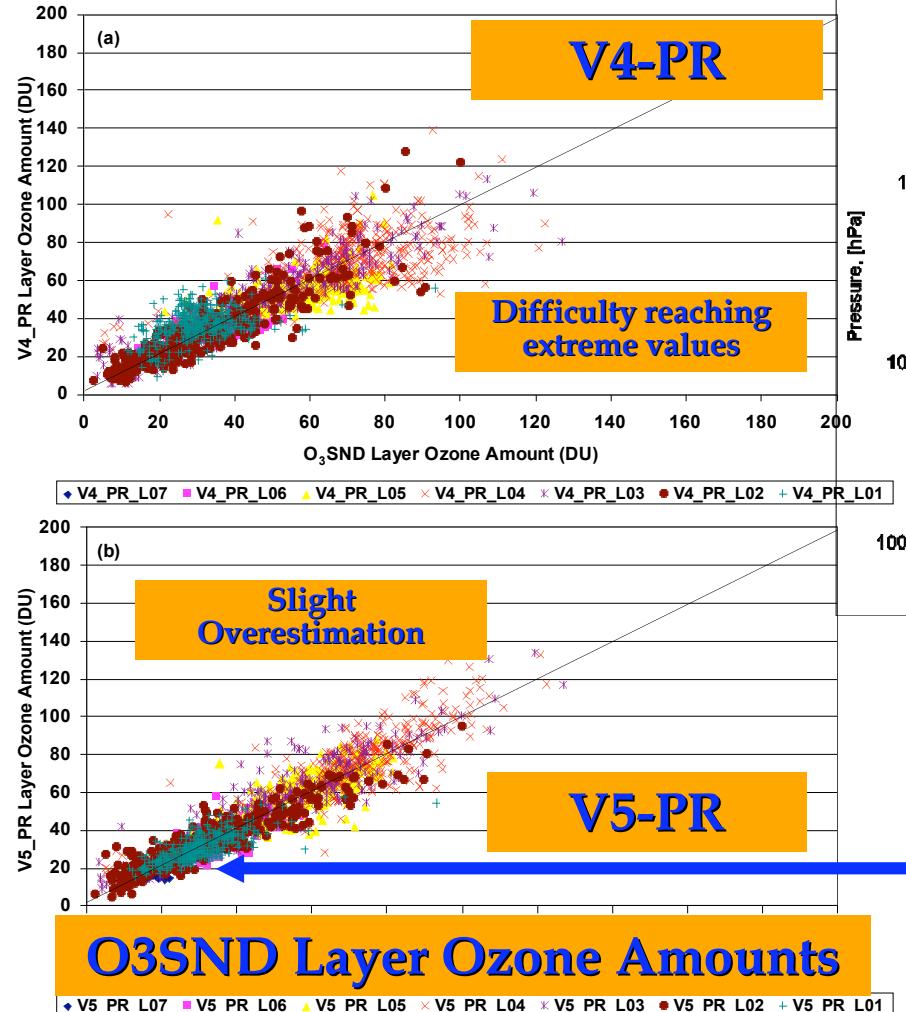


V5.0.7 O3WGT=1.0 is Chosen

# AIRS V5 and V4 Retrieved Layer Ozone Amounts vs. O<sub>3</sub>SND Layer Ozone Amounts



**PR Layer Ozone Amounts**



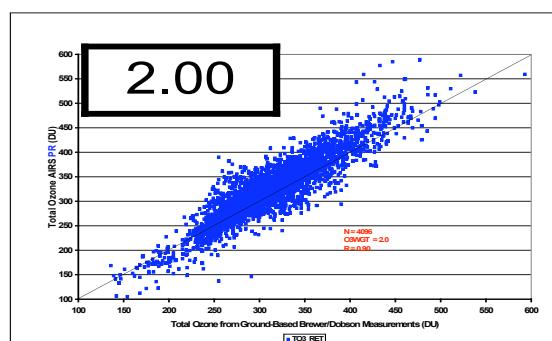
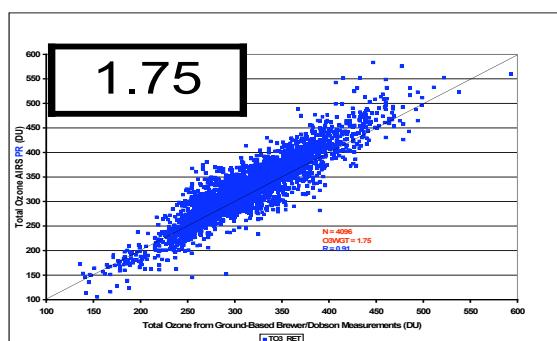
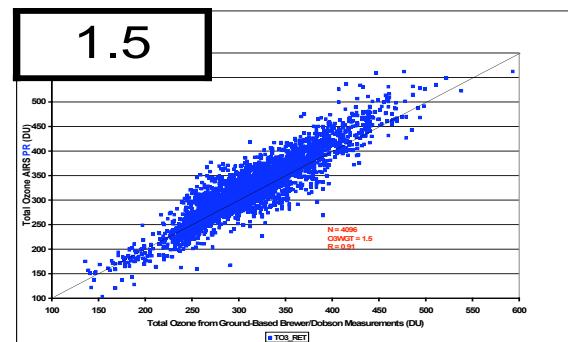
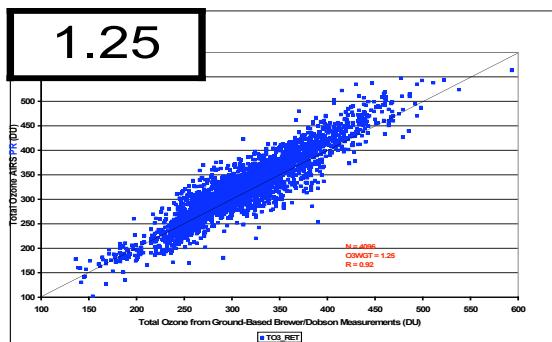
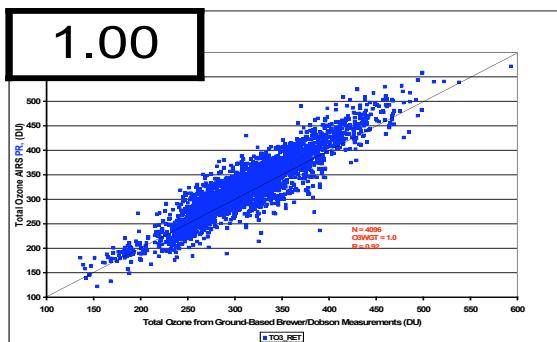
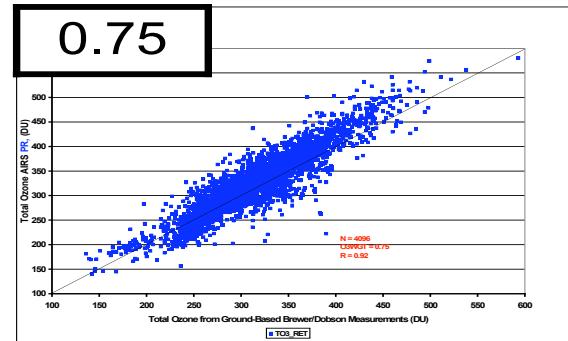
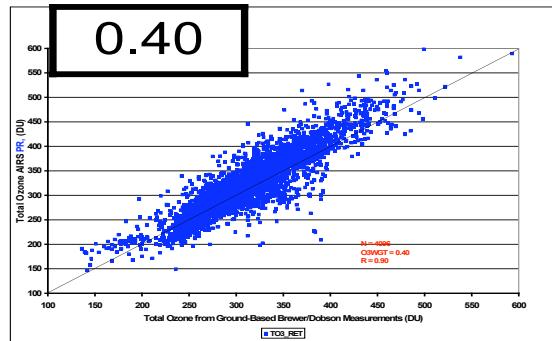
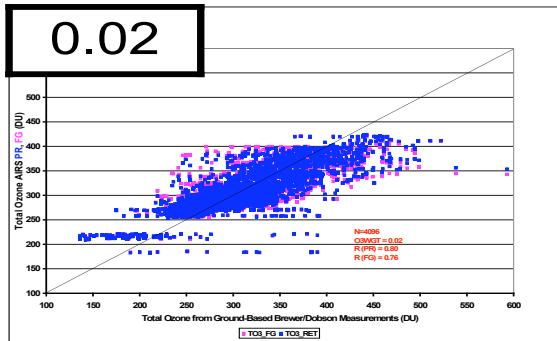
**V5 Climatology First Guess Helps Physical Retrieval for the Lowest Layer 1 (1000-260 mb)**

Layer 7	4	8 mb
Layer 6	8	16 mb
Layer 5	16	32 mb
Layer 4	32	66 mb
Layer 3	66	126 mb
Layer 2	126	260 mb
Layer 1	260	1100 mb

\* V4\_PR\_L07 ■ V4\_PR\_L08 ▲ V4\_PR\_L05 × V4\_PR\_L04 \* V4\_PR\_L03 ● V4\_PR\_L02 + V4\_PR\_L01



# O3WGT for V5.0.7



## O3WGT Factors

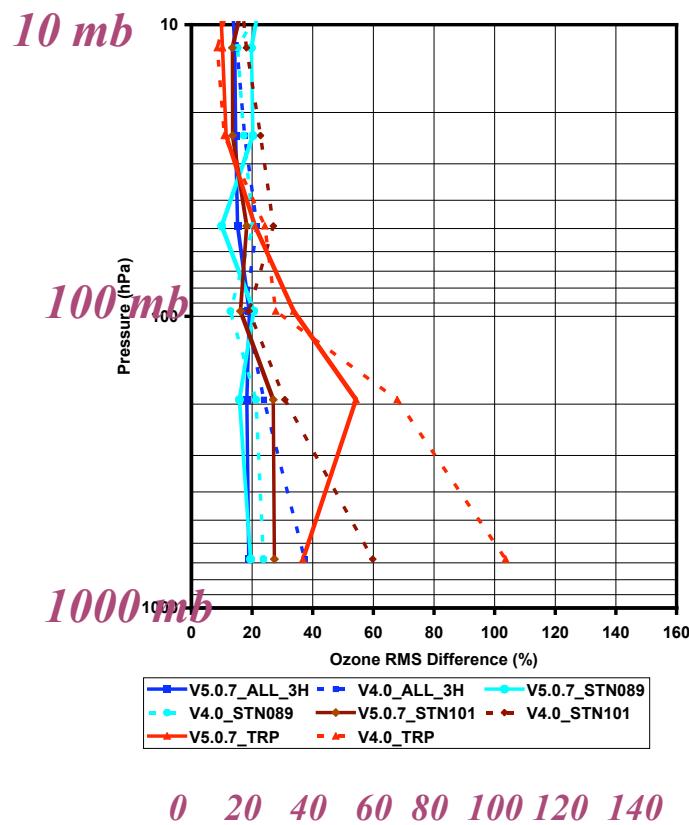
<b>0.02</b>	<b>0.40</b>	<b>0.75</b>
<b>1.0</b>	<b>1.25</b>	<b>1.50</b>
<b>1.75</b>	<b>2.0</b>	<b>NONE</b>

# V5 Physical Retrievals - Different Stations

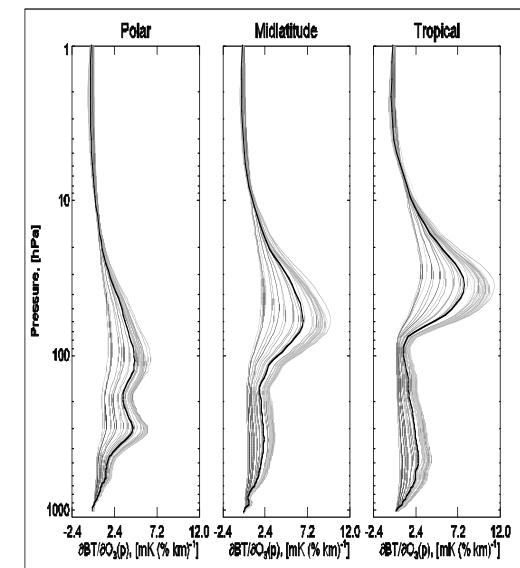
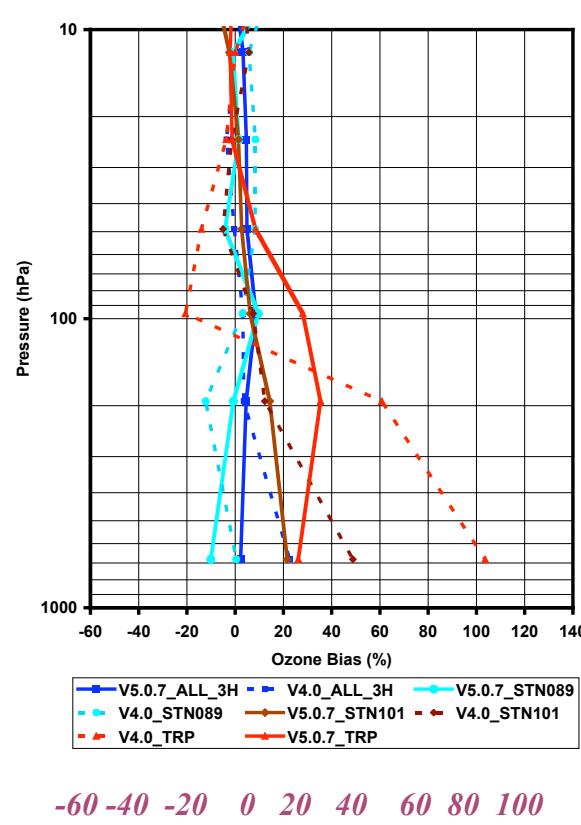
ALL (N=353), STN 089 (N=53, NH),  
STN 101(N=50,SH), Tropics (N=54, ±12HR)



## RMS Difference



## Bias



**V5 Climatology First Guess Helps Physical Retrieval for the Lowest Layer 1 (1000-260 mb)**

V4 Dotted lines, V5 Solid Lines

ALL\_3H STN089 STN101 TRP\_12H ALL\_12H